United Technologies Research Center

Methodology for Architecting Energy Systems in Ultra Low Energy Communities

Energy System Architecting Tool (ESAT)

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for

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Why Distributed Power Systems / Energy Microgrids?

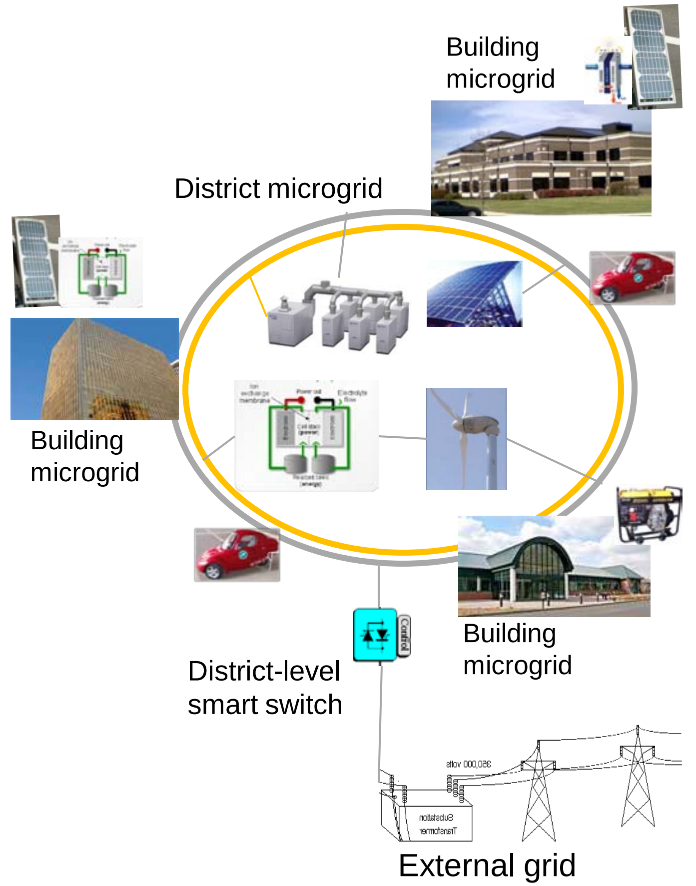
Security of supply, reduced energy, and minimized environmental impact

Security of energy supply

- ***Vulnerable loads*** served under all operating conditions.
- 'Customizable' ***power quality and reliability***
- **Seamless transition** between islanding and off-grid operation

Reduced energy costs and environmental impact

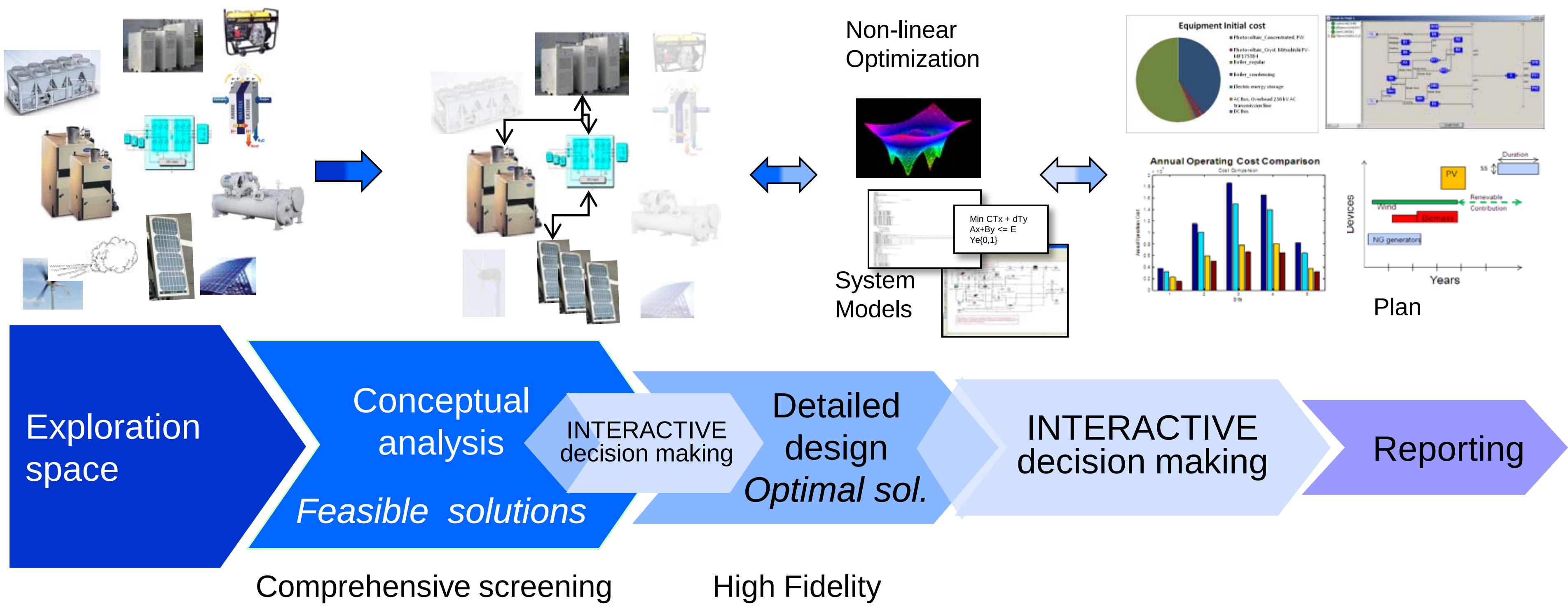
- Improved power systems architectures
  - ***Waste heat utilization***
    - 85-90% fuel utilization vs. 40-50% for central power
  - ***Renewable sources with energy storage***
  - ***Maximize ROI***
- Integrated demand/supply management:
  - ***Reduced energy consumption/cost,***
  - ***Peak shaving***
- **Decrease** in T&D **losses and** required **infrastructure**



- **Energy microgrids are distributed power systems with the capability to work seamless in islanding and grid-connected modes.**
- **They include thermal and electrical systems**

Energy Microgrids Architectural Synthesis Tool: Overview

The objective is to develop methodology and prototype tools to identify best distributed power system architectures;



- Extensible to energy demand technologies for NET Zero Architectures
- Provides ‘if-then’ scenario and sensitivity analysis capability
- Economics, performance and environmental metrics are some of the metrics

Energy Microgrids Architectural Synthesis Tool: Process

Requirements (default & editable) → Exploration space → Conceptual analysis: *Feasible solutions* → INTERACTIVE decision making → Detailed design: *Optimal sol.* → INTERACTIVE decision making → Reporting

Component Model Library

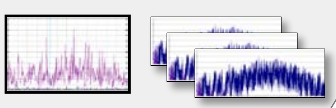
- Sources
- Storage
- Loads
- Converters

Economic models

Cost, utilities

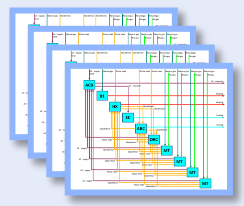
Location and weather

Loads

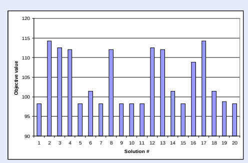


Objectives and Constraints

Super-structure generation



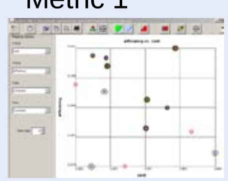
Linear Optimization



N 'best' solutions

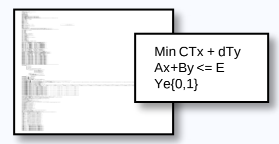
First comparison

Metric 1

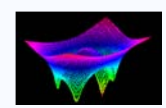


Metric 2

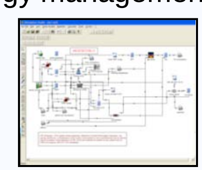
Automatic model generation



Non-linear Optimization

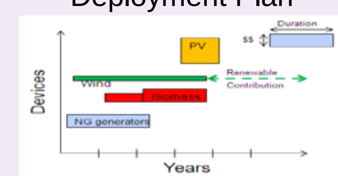


Best architecture and energy management



Visualization and reporting

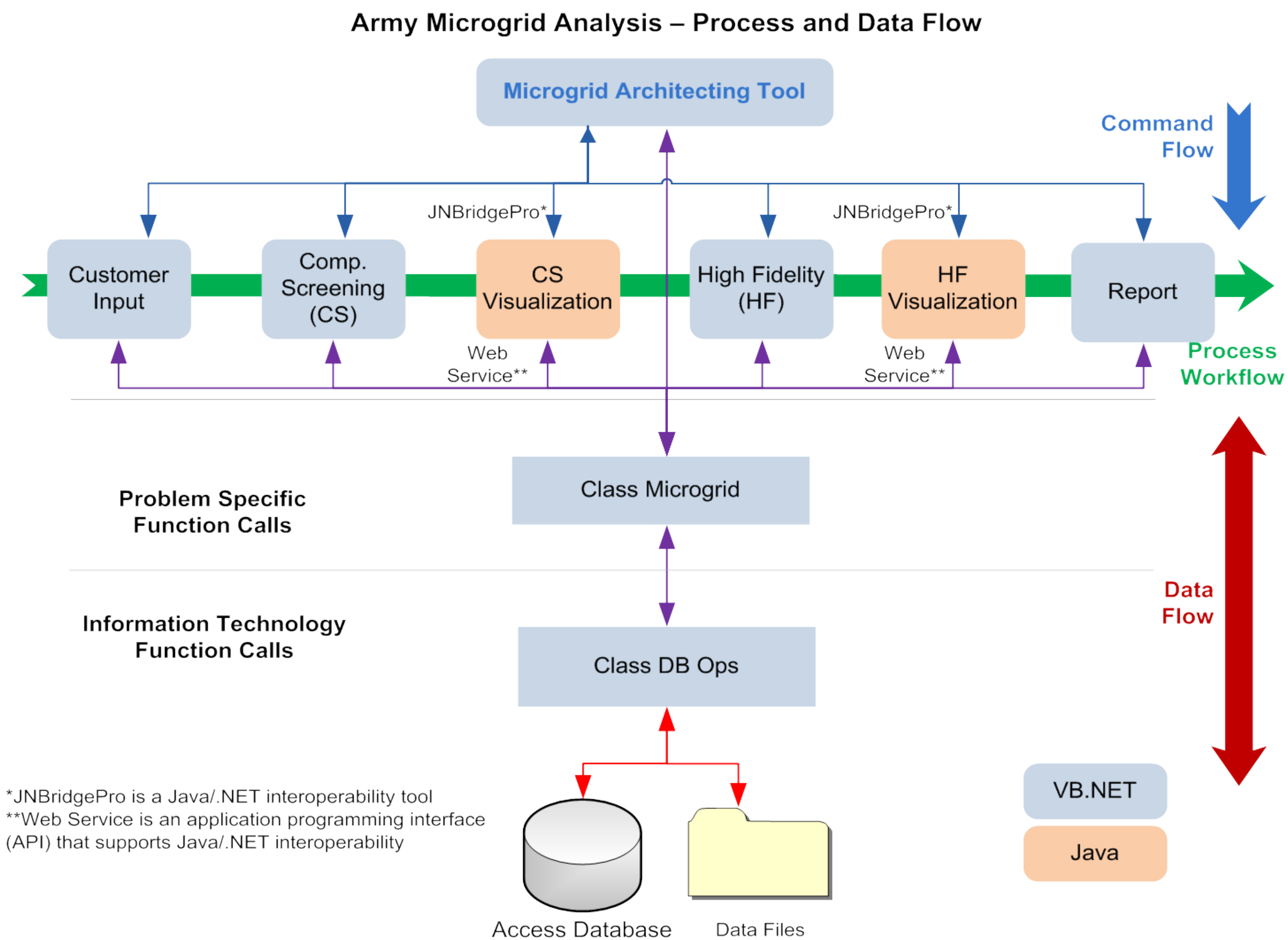
Deployment Plan



Interactive process

Energy Microgrids Architectural Synthesis Tool: Architecture

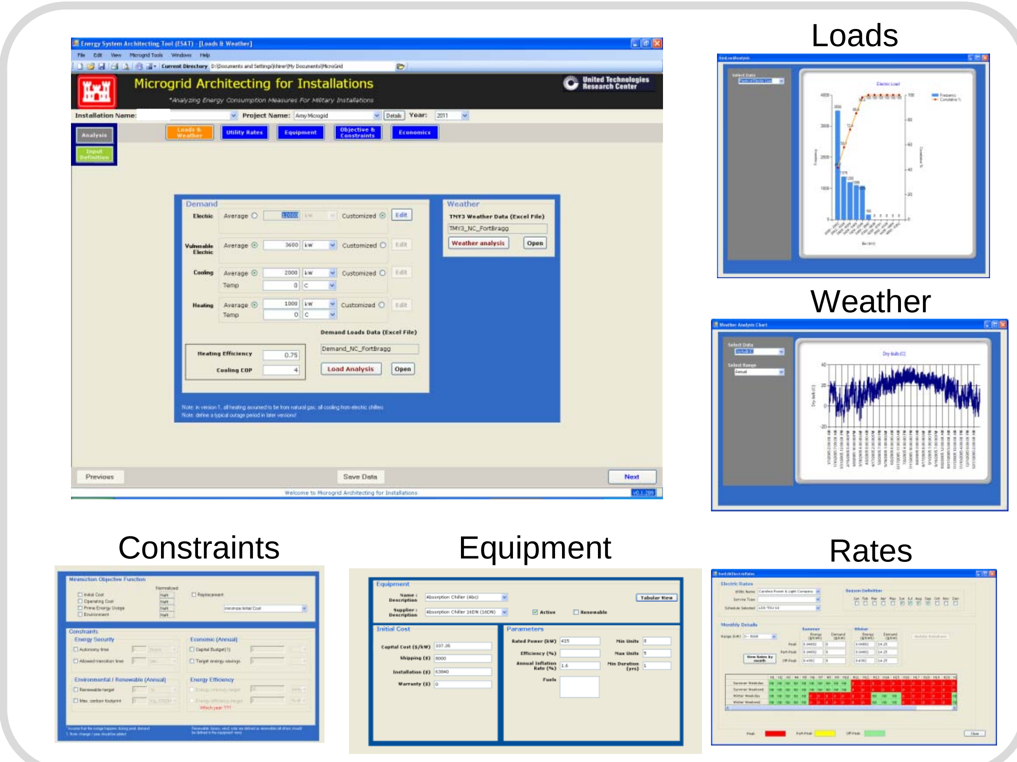
- Front end and coordination engines (or classes) are based on .Net
- Java to VB libraries support synchronous message passing between modules
- Extensible architecture to include demand and supply problems



Energy Microgrids Arch. Synthesis Tool: User Interfaces: Inputs

Front end and coordination engines (or classes) are based on .Net

Graphics User Inputs
(pre-populated by default values)



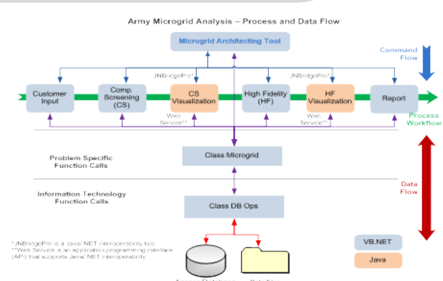
User-selected objectives

- Minimize lifecycle cost
- Minimize environmental impact
- Minimize operational cost

Inputs Constraints

- Budget
- Renewable usage

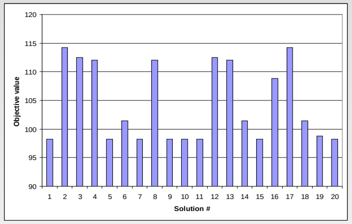
Databases
Equipment models, economics, loads, outputs, requirements, constraints, etc.



Energy Microgrids Architectural Synthesis Tool: Output Metrics

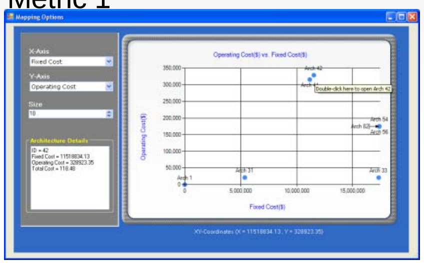
Performance metrics will be visualized and exported in the form of a report

Architectures comparison



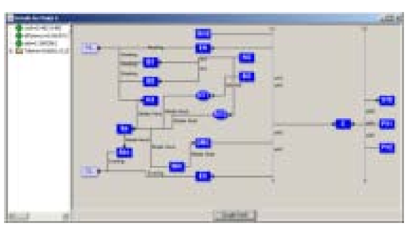
N 'best' solutions

Metric 1

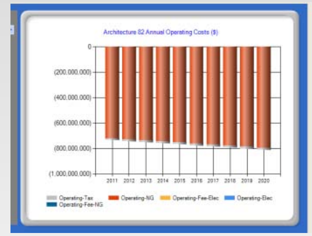


Metric 2

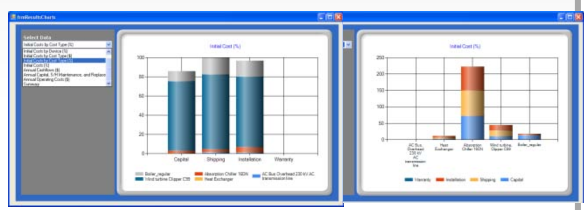
Architectural diagrams



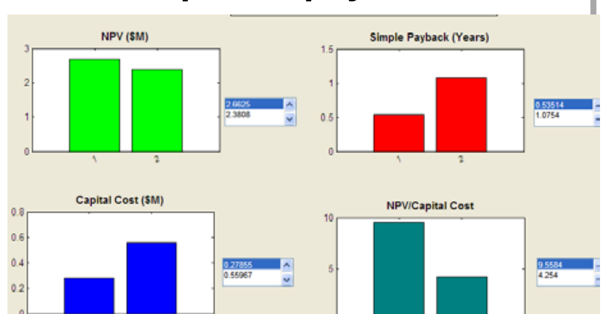
Capital cost & cashflows



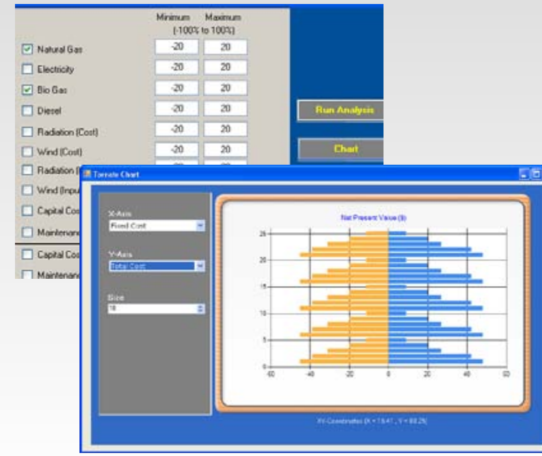
O&M cost, detailed utility costs



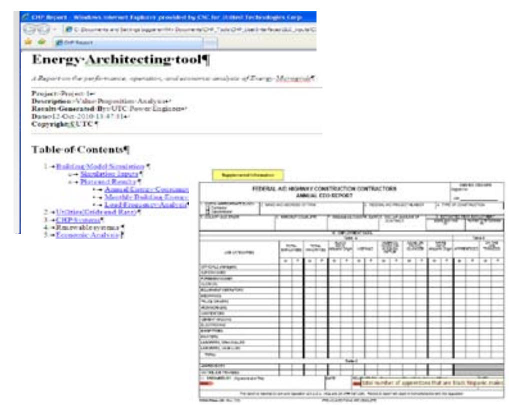
Economic metrics: NPI, simple and compound payback, ROI



Simple and compound sensitivity analysis



Report Generation



Energy Microgrids Architectural Synthesis Tool: Sample Problem

, *Objective: Lifecycle cost Minimization*

Objective

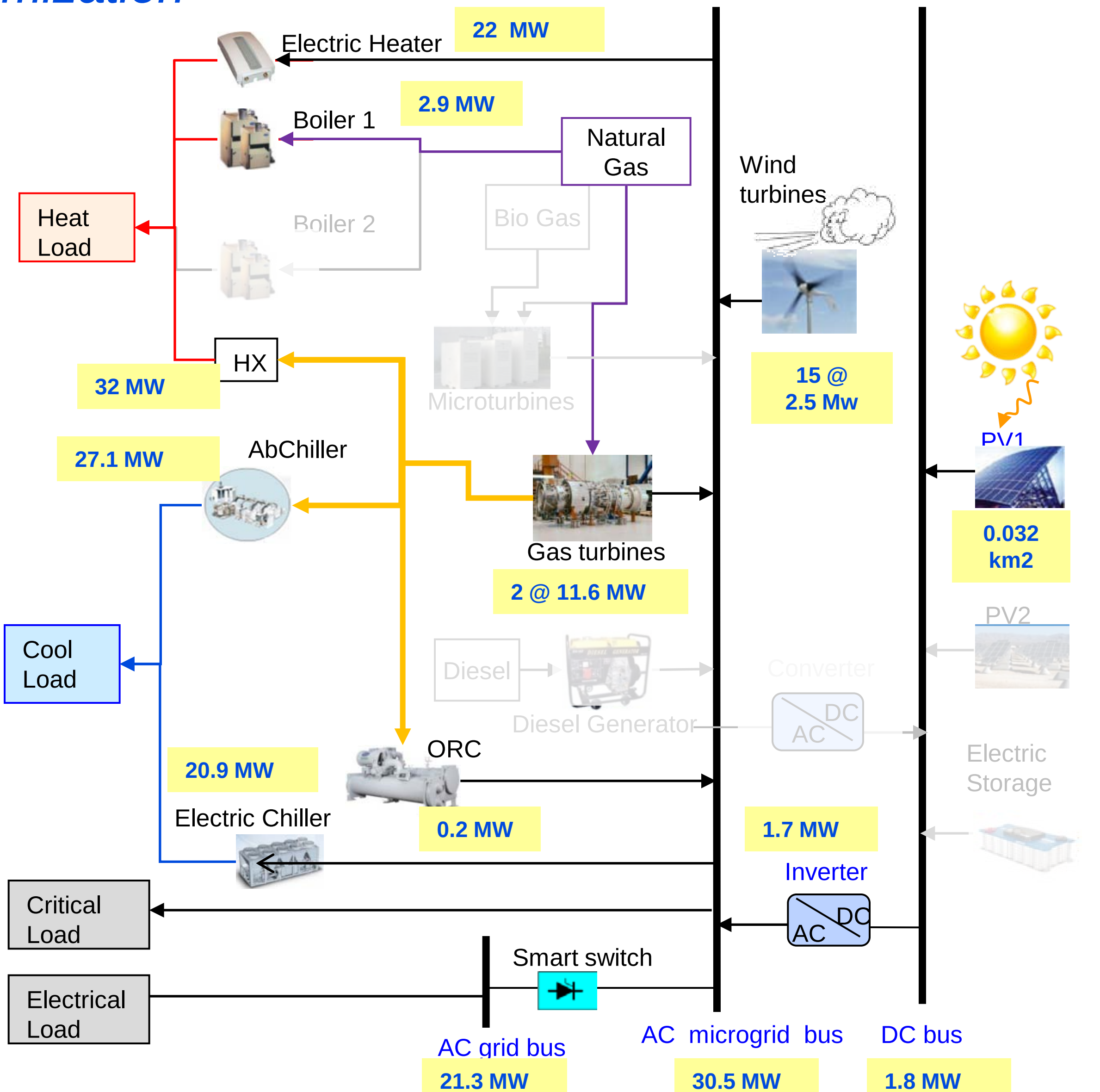
- Minimize total 20-yr. discounted cost
  - Fixed cost
  - Operating cost
    - Discounted
    - Inflation accounted for
  - Replacement cost

Constraints

- Meet load at all times
- Meet critical load during islanding
- Min renewable = 7.5%
- Max renewable
  - Area $4km^2$

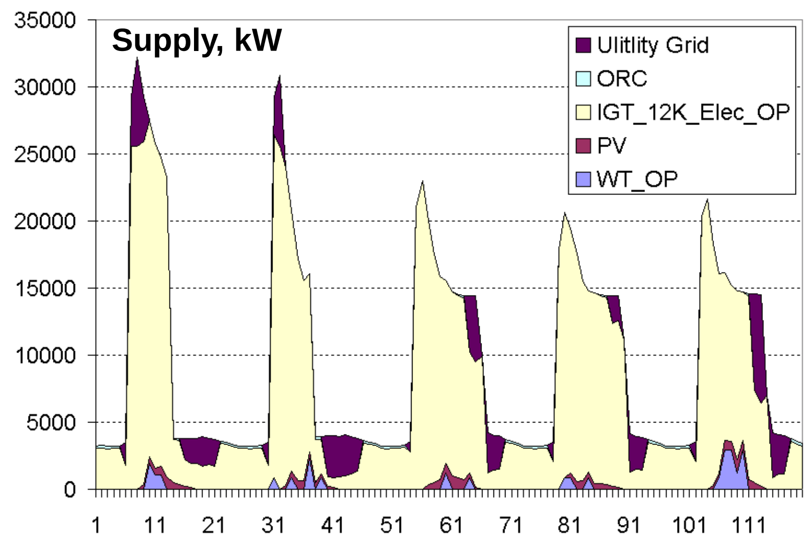
Assumptions

- Demand and energy charges for utility included
- Load profiles derived using DOE2
- Life = 20 years

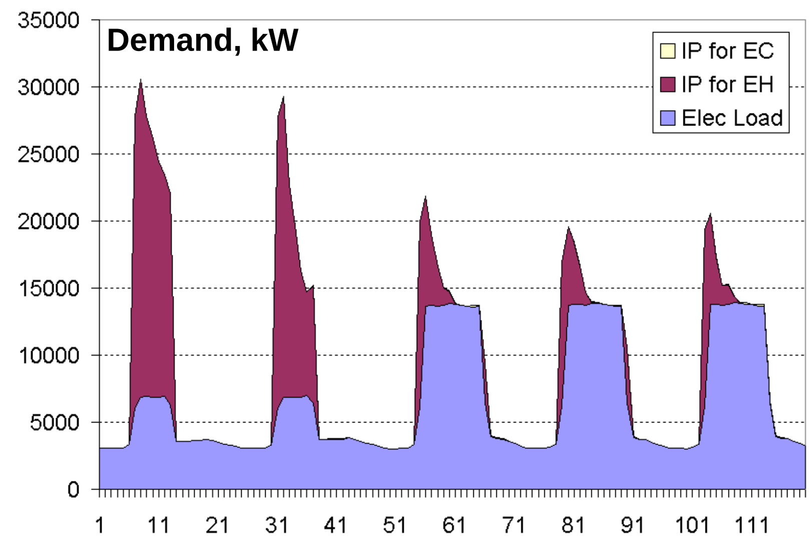


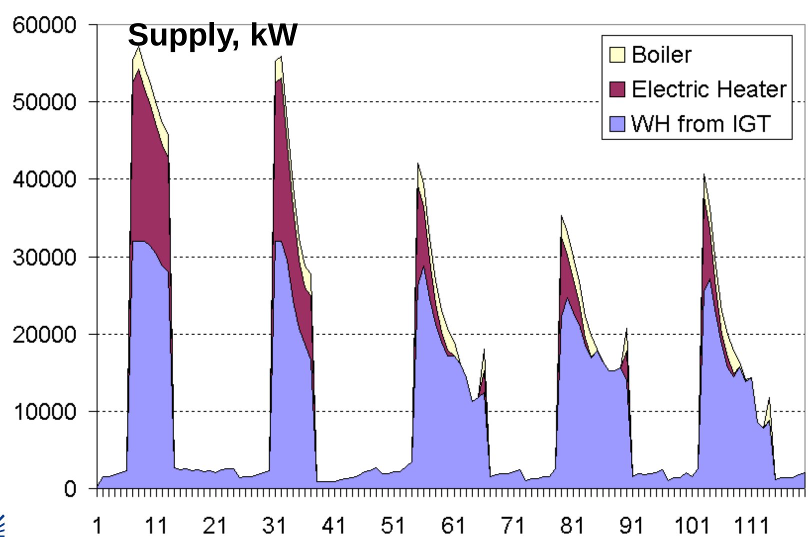
Verification of Results

Supply always more than to demand → Ensures Energy Balance
No Excess Supply → Consistent with Cost Minimization

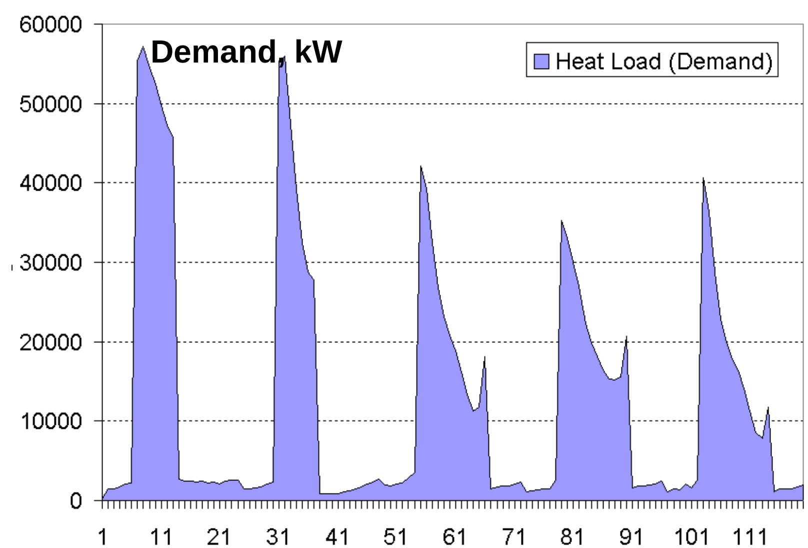


Electricity





Heat

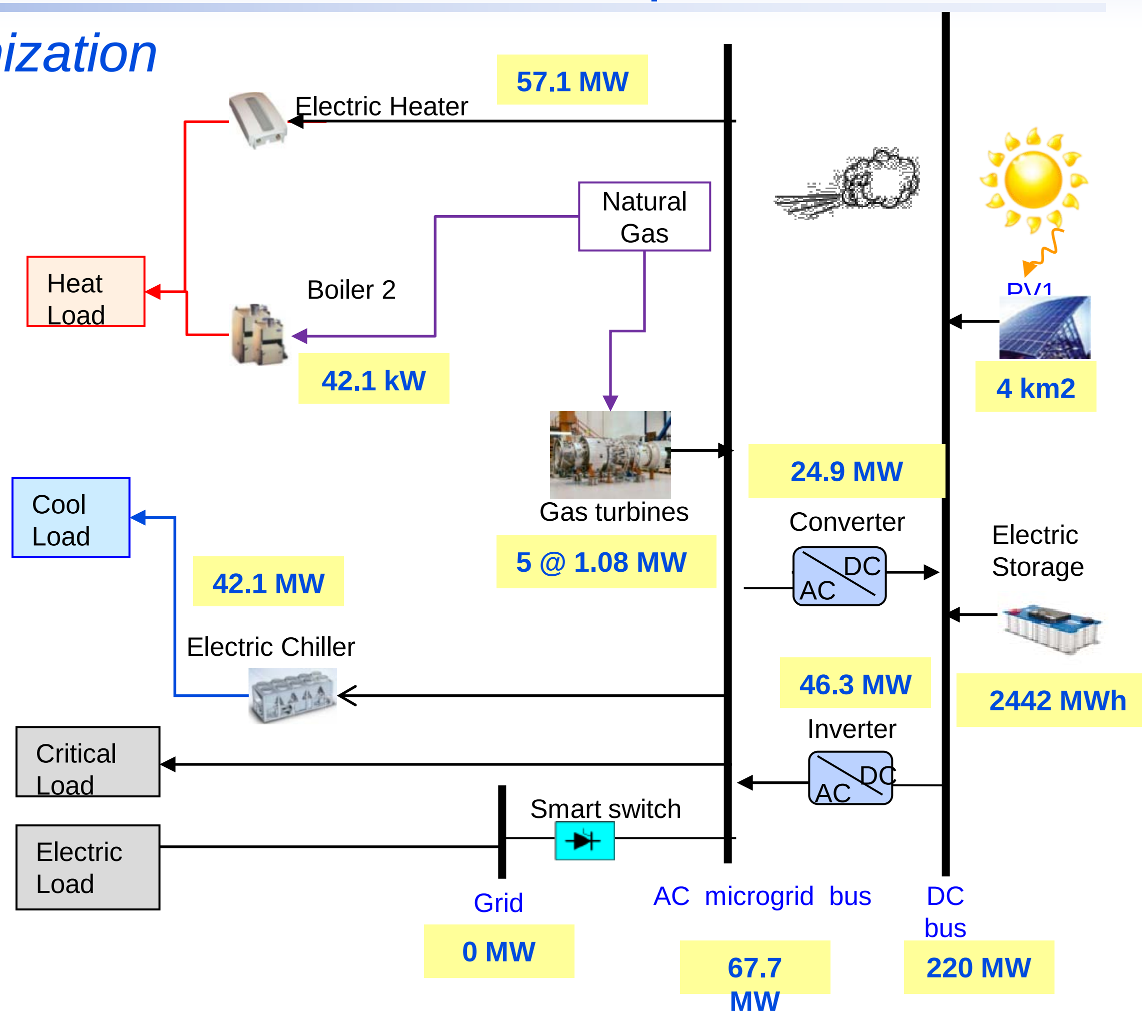


Sensitivity to Objective Function Selection, Sample Problem

Objective: CO_2 release minimization

Observations

- Max possible PV selected
- PV preferred over WT, due to high solar in selected site
- Significant reduction in operating cost achieved (with significant initial cost increase)
- Utility Grid independent System



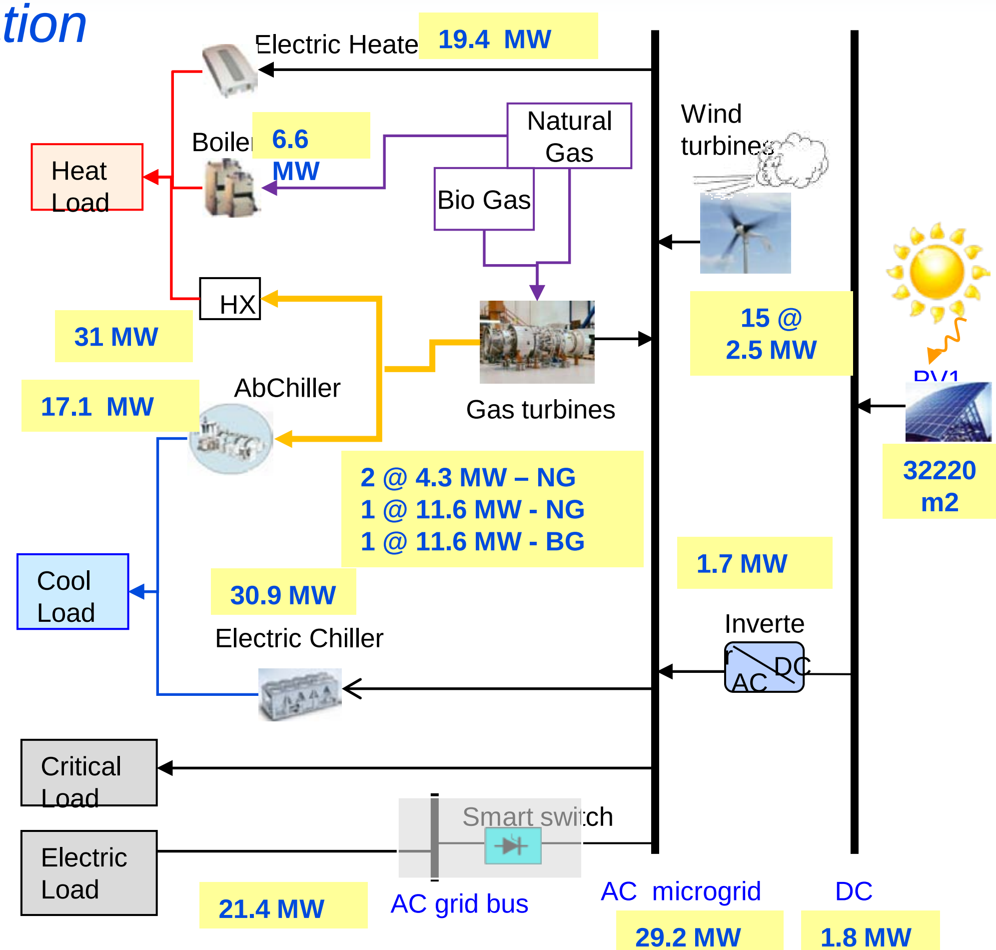
	Initial Cost	Operating Cost (Discounted over 20 yrs	Primary energy (kWh/year)	CO_2 (kg/year)
Reference	$ 202 M	$137.3 M	27.26×10^6	4.94×10^6
CO2 Minimization	$ 23,227 M	$0.78 M	0.175×10^6	0.007×10^6

Sensitivity to Objective Function Selection, Sample Problem

Objective: Lifecycle cost Minimization
Sensitivity to NG price

Observations

- No architecture change for 20% increase in NG Cost
- For 50% increase: Some IGT load is transferred from NG to BG
- Increase in primary energy due to lower efficiencies for BG
- Higher CO_2 due to BG
- 27% reduction in annual NG consumption



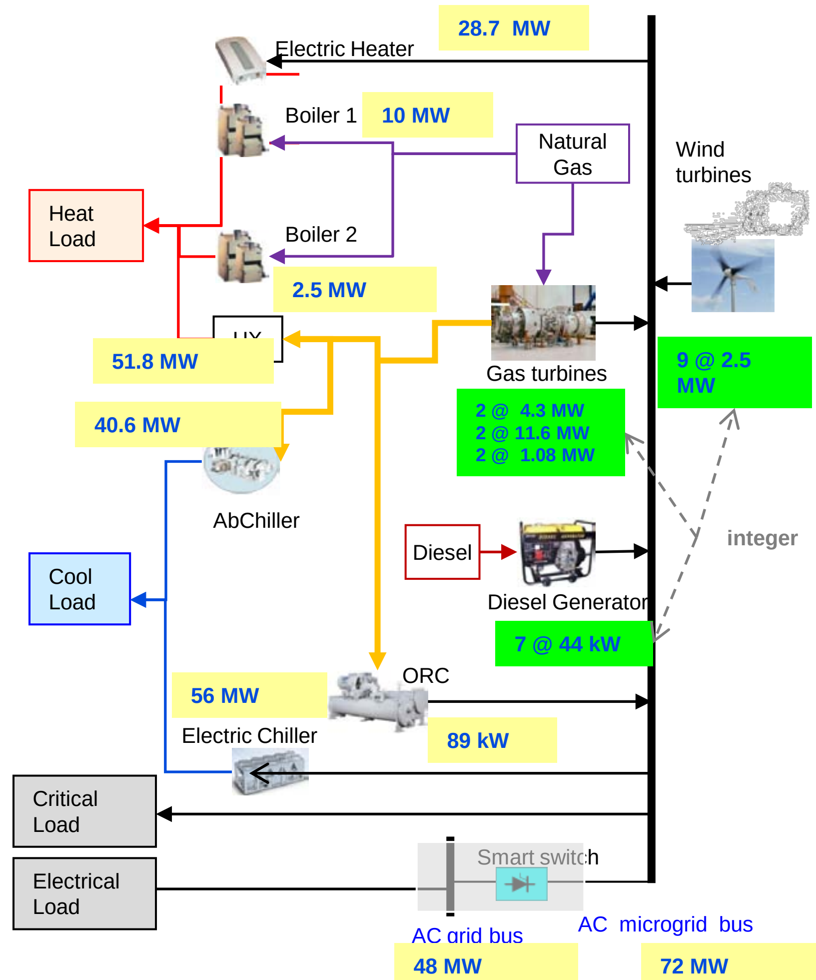
	NG Consumption (kW/Year)	Initial Cost	Operating Cost (Discounted over 20 yrs	Primary energy (kWh/year)	CO_2 (kg/year)
Reference	$17.5x10^6$	\$202.0 M	\$137.3 M	$27.26 x10^6$	$4.94 x10^6$
150% NG	$12.7x10^6$	\$203.9 M	\$178.4 M	$30.40 x10^6$	$6.40 x10^6$

Project Plan : Sample Results

Project Planning Parameters

Project duration = 9 years
Renewable targets
    1st year = 1%
    Annual increment = 1%
Annual Budget = $ 9 M
Inflation rate =1.5 %
Discount rate = 0 %
Minimize Budget overruns → Strict renewable

Optimized final architecture



Annual installed capacity

		Year								
		1	2	3	4	5	6	7	8	9
Electric Heater	MW				28.7					
Heat Exchanger	MW		51.8							
Absorption Chiller	MW	16.9			1	1.2	0.1	5.4	5.1	
Electric Vhiller	MW		55.9							
ORC	MW		0.1							
Boiler 1	MW							10		
Boiler 2	MW	1	1.5							
Wind Turbine	#	1	1	2		2	1	1		1
Disel Generator	#			7						
Gas Turbine 1	#						2			
Gas Turbine 2	#				1				1	
Gas Turbine 3	#			2						

Annual budget plan ($M)

Year								
1	2	3	4	5	6	7	8	9
10.2	9	10.2	9	9	9	9	9	9

Energy Microgrids Architectural Synthesis Tool: Strengths

- The selected architecture does not have to be assumed a-priori.
- The entire framework is interactive.
- Considers non-linear behavior of various technologies/devices.
- The framework is extensible to include energy supply, demand and storage as a holistic approach to obtain Net-Zero solutions.
- The selected framework is scalable to consider buildings, campus or district.
- The optimal energy system architecture could satisfy vulnerable loads in islanding mode.
- ESAT developed an staged plan (development plan) that satisfies budget constraints and renewable mandates during installation.
- Includes special consideration of energy solutions that consider thermal and electrical losses as well as cost of pipes and transmission lines (work in progress).

Energy Microgrids Architectural Synthesis Tool: Limitations

Future Developments

- Energy demand /supply: ESAT is *currently* focused on the architecting of energy supply side. An extension to include demand systems is planned.
- Reliability: Currently, ESAT is a purely deterministic methodology (MTBF and maintenance cost *are* included, but still not the potential cost of an stochastic power outage).
- Uncertainty: The current ESAT version, does not include uncertainties in weather or building loads forecasts. Sensitivity analysis is provided.
- Include GIS (Graphical Information System): Interfacing commercially available GIS software with ESAT will significantly enhance its capability, in terms of simplifying data gathering for users and visualizing results in geographical environment.

Q&A

For further questions, please contact:

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